Organized Convection: Diabatic Heating Profiles and Initiation

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1. Introduction

As defined here, "organized convection" comprises clustered raining convective towers (associated with bottom-heavy diabatic heating profiles) and an extensive stratiform anvil (associated with top-heavy profiles) [bottom left]. A system-average of all profiles often results in a top-heavy profile (i.e. peak above the melting level). Such convection occurs in all tropical ocean basins [bottom right], influences the atmos. circulation (coupled to the structure of heating), affects vertical momentum transports, and may be relevant for understanding cloud-radiative feedbacks. We aim to increase our understanding of, and further, parameterize such convection in the GISS GCM.

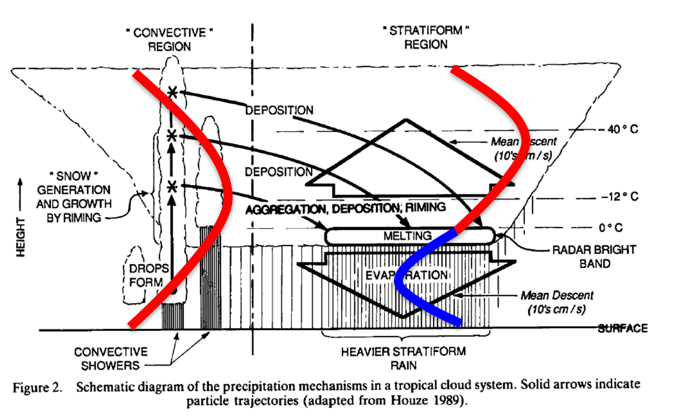
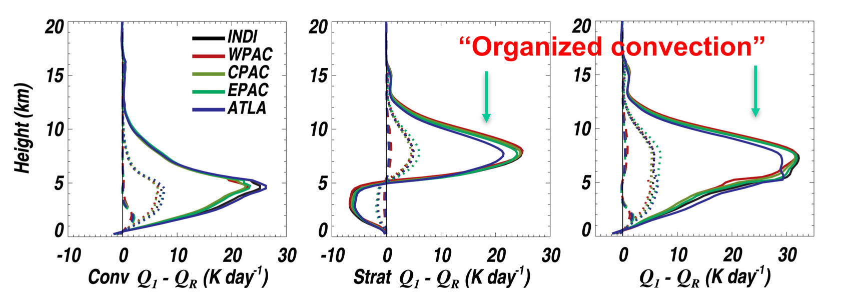
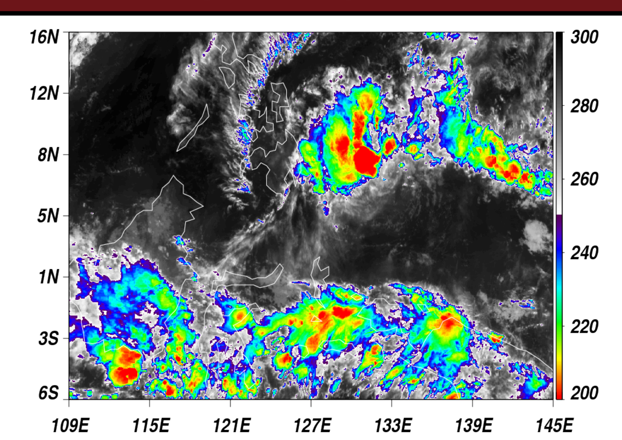


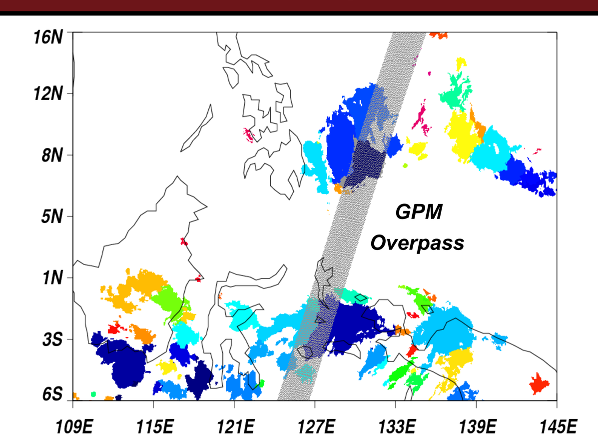
Figure 2. Schematic diagram of the precipitation mechanisms in a tropical cloud system. Solid arrows indicate particle trajectories (adapted from Houze 1989).



Elsaesser et al. (2010), Figs 5 and 6.

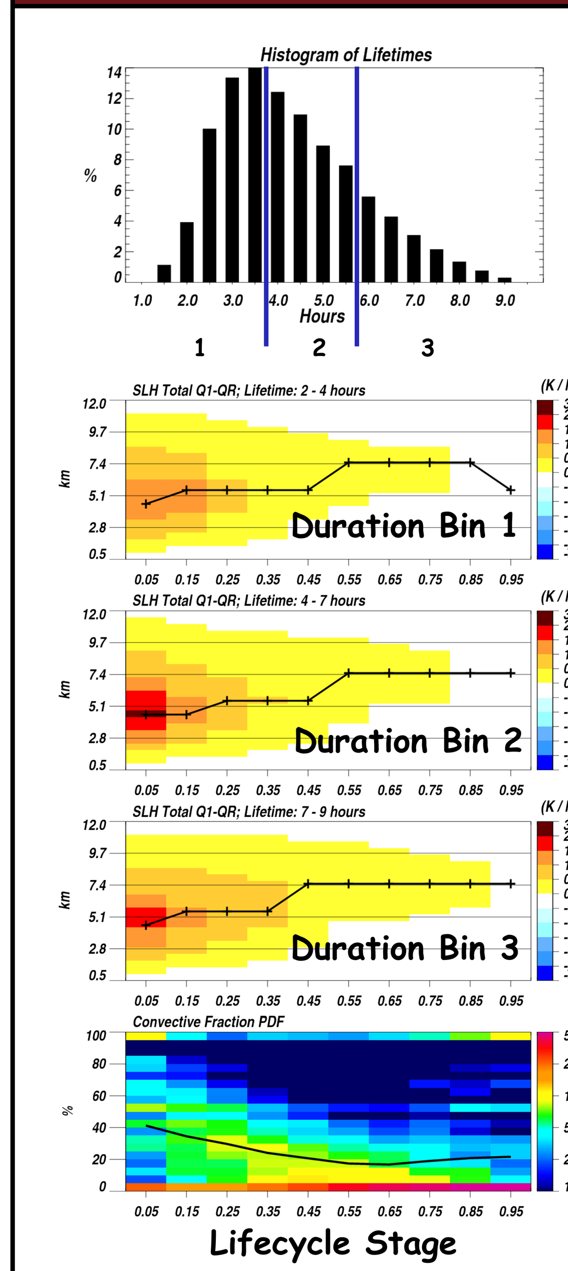
2. Tracking Organized Convective Systems





A variation of the Fiolleau and Roca (2013) convective system tracking algorithm is applied to the CPC 30-min, 4-km IR data set. Systems must be over 25 x 25 km^2 in spatial extent at some point in their lifecycle to be tracked. All available GPM overpasses are mapped to convective systems, and we store life-stage, duration, size, diabatic heating profiles, convective fraction, and rainfall.

3. Diabatic Heating Profile Structures vs. System Size and Duration



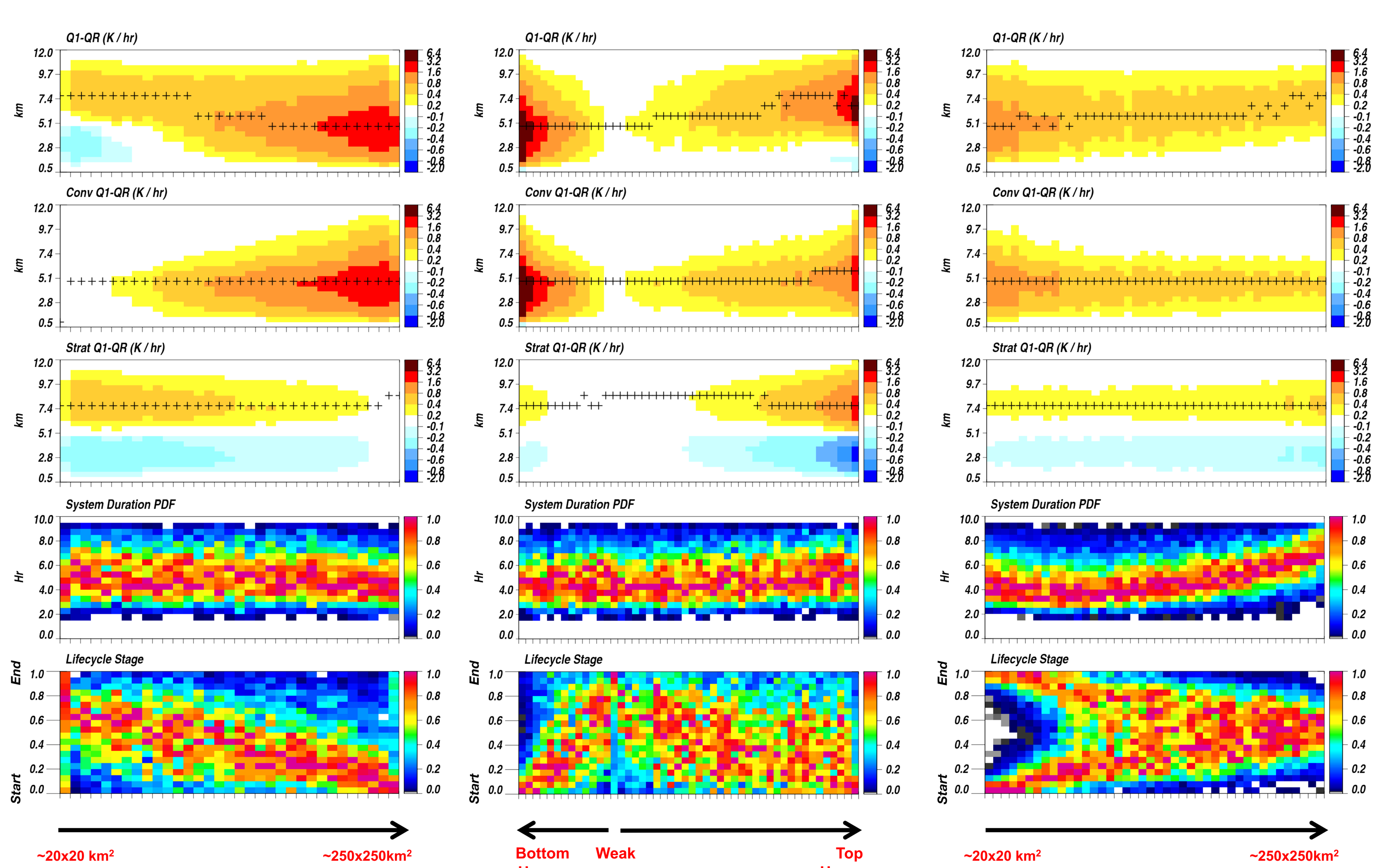
❖ [Left] For different durations, composite heating profiles look as expected: more bottom-heavy early in the lifecycle; top-heavy heating later; larger size (IR cloud shield) in later stages. However, the amplitude of heating decreases as the system matures (which may suggest an average of diverse profiles), and the PDFs of conv. fractions (as a function of stage) suggest substantial variability. Are composites misleading?

❖ [Right] To assess the representativeness of composites, we look at PDFs of duration and lifecycle stage as a function of convective rainfall fraction, heating profile top-heaviness, and system size.

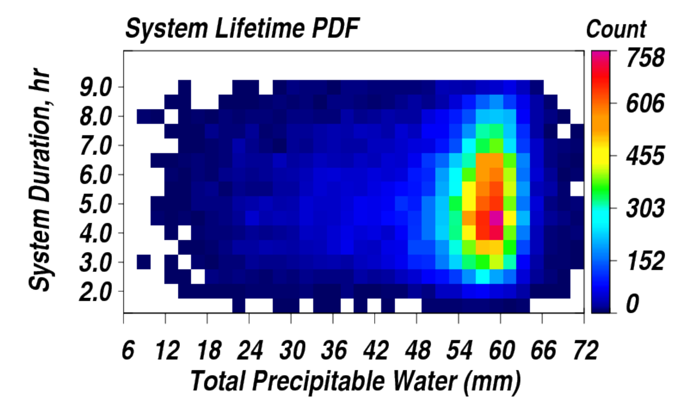
Hypotheses: *lifecycle characterized by top-heavy heating later; system largest later in cycle, and thus larger size is associated with top-heavy heating; larger systems last longer, and thus longer systems may have more top-heavy heating.*

Findings: *bottom- (top-) heavy distinctly found at initiation (termination) of the system, but much variability over majority of lifecycle; weak relationship between size/duration of system and heating profile; size and duration very coupled.*

Interpretation: *organization, if defined by "heating structures", may be independent of system size/duration; perhaps an oscillation instead of systematic progression of organization with lifecycle stage?*



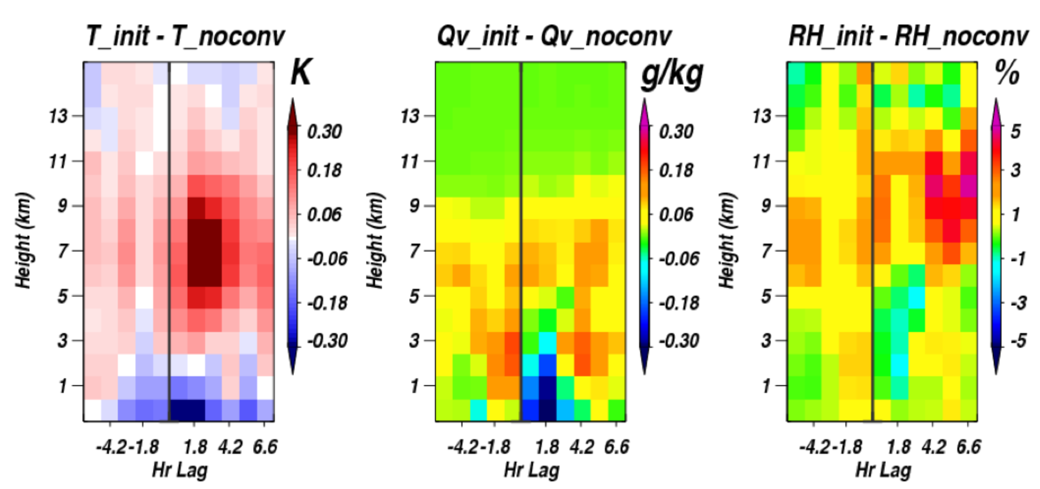
4. Environment During Initiation



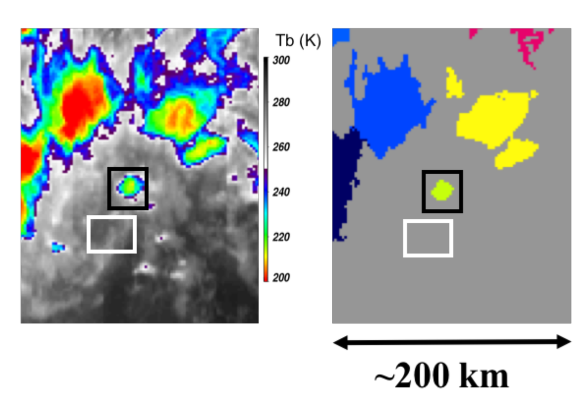
(Left) While organized systems most often occur for total precipitable water (TPW) values above 50 mm, no clear relationship exists between TPW and system duration.

Even in an overall moist-large scale environment, organized convection is still patchy (example bottom/left) Local/Mesoscale decreases in lower-mid tropospheric temperatures (i.e. decreased conv. inhibition) or increases in Qv, hours prior to convection, may be important for understanding why organized convection initiates where it does in an overall favorable large-scale state.

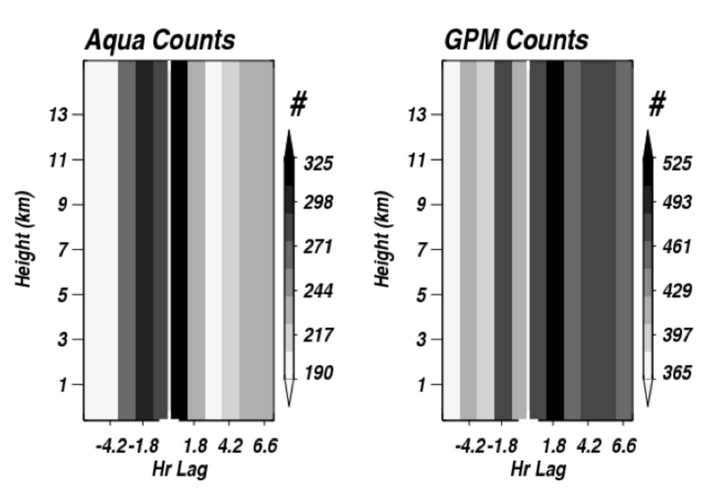
(Right) From L-R, composite AIRS/AMSU T, Qv, and RH for initiating organized deep convection minus estimates from nearest non-convective region as a function of hour lag relative to initiation.
(negative Hr Lag = environment before deep convection; positive = after).



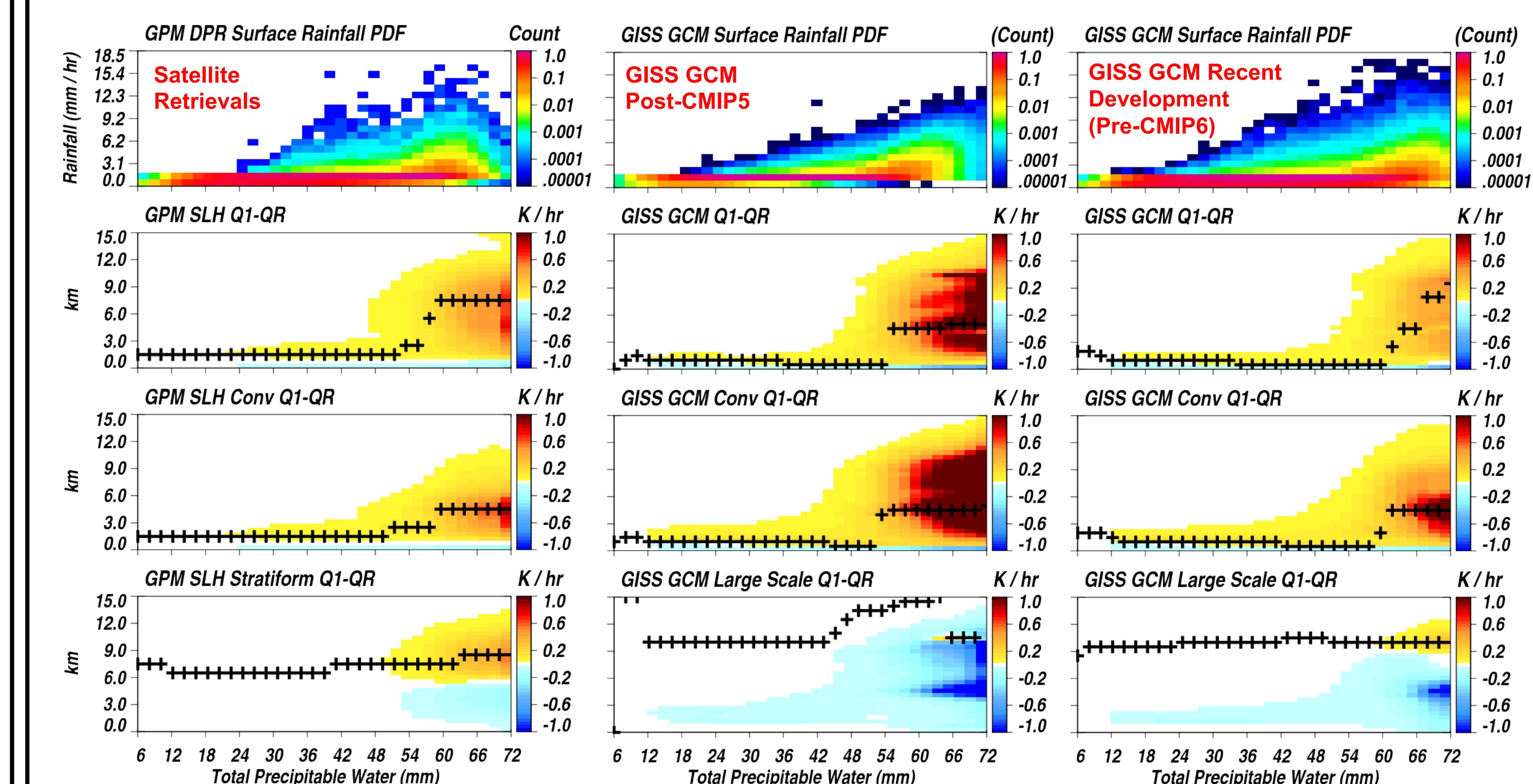
(Below) Zooming in on example of initiating organized convection (black box) and nearby non-convective area (white boxes).



(Right) Number of co-located Aqua and GPM overpasses as a function of hour lag relative to deep convective initiation.



5. Informing GCM Development



- Most organized convective systems occur for TPW > 50 mm; thus, we see a corresponding rise in the altitude of peak diabatic heating for such TPWs (largely driven by the stratiform mode) (left column).
- Older versions of the GISS GCM were deficient in this representation (middle column, post-CMIP5), with too strong convective heating, and too weak stratiform heating.
- (right column) We use the GPM heating products to guide development of the GISS GCM cloud parameterizations (here, a version of our GCM that will be a candidate for ModelE3, contributing to CMIP6), which results in a better simulation of diabatic heating.
  Specific improvements include:
  - *observations-based (including MC3E and NAMMA) parameterization of convectively detrained ice sizes and number concentrations (Elsaesser et al. 2017) [relevant to cloud system schematic for deposition / aggregation arrows in Introduction];*
  - *the development of a cold pool parameterization (Del Genio et al. 2015) [toward addressing the role of the mesoscale in deep convection initiation, as discussed in section 4];*
  - *incorporation of MG2 microphysics (Gettleman et al. 2015) into the large-scale cloud routine that evolves the detrained cloud condensate for stratiform cloud development (work by Andy Ackerman/GISS).*

6. Upcoming Work

❖ Our focus thus far has been on system-average diabatic heating profiles; we are in the process of investigating whether duration and/or system size is tied to the spatial location of the stratiform and convective profiles in a given system (i.e. whether all stratiform heating is clustered together, and spatially separate from convective heating, versus a random assembly of all profiles). This final aspect will be part of a journal article on heating, system sizes, and duration, and "organization".

❖ Extend our analysis of the environment to lifecycle stages beyond initiation. Questions we will address include: if systems go through oscillations in size and heating structures, what thermo-dynamic parameter(s) are most related to such variations? When systems of a given duration terminate, was there an "observable" change in the thermodynamics of the environment? What is the role of dynamics (e.g. mesoscale surface convergence, wind shear)?

7. References

Del Genio, A.D., J. Wu, A.B. Wolf, Y. Chen, M. Yao, and D. Kim, 2015: Constraints on Cumulus Parameterization from Simulations of Observed MJO Events. *J. Climate,* **28**, 6419–6442.

Elsaesser, G. S., A. D. Del Genio, J. Jiang, and M. van Lier-Walqui, 2017: An Improved Convective Ice Parameterization for the NASA GISS Global Climate Model and Impacts on Cloud Ice Simulation. *J. Climate*, **30**, no. 1, 317-336, doi:10.1175/JCLI-D-16-0346.1.

Elsaesser, G.S., C.D. Kummerow, T.S. L'Ecuyer, Y.N. Takayabu, and S. Shige, 2010: Observed Self-Similarity of Precipitation Regimes over the Tropical Oceans. *J. Climate,* **23**, 2686–2698.

Fiolleau, T., and R. Roca, 2013: An Algorithm for the Detection and Tracking of Tropical Mesoscale Convective Systems Using Infrared Images From Geostationary Satellite. IEEE Trans. Geosci. Rem. Sens., 5, 4302-4315.

Gettelman, A., H. Morrison, S. Santos, P. Bogenschutz, and P.M. Caldwell, 2015: Advanced Two-Moment Bulk Microphysics for Global Models. Part II: Global Model Solutions and Aerosol-Cloud Interactions. *J. Climate,* **28**, 1288–1307.